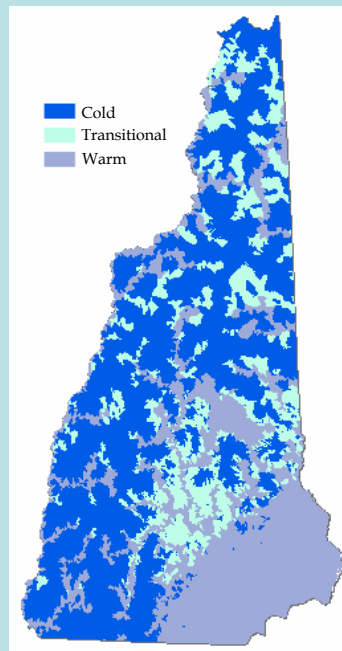
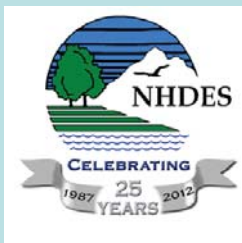
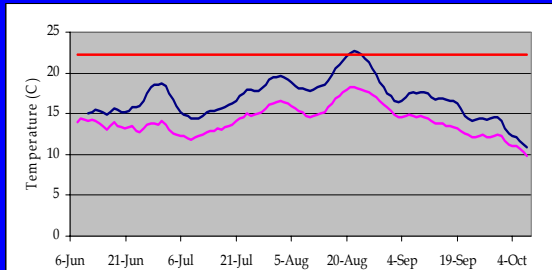


NH stream type thermal regimes: towards the development of in-stream water temperature criteria

David Neils, NH DES

7- day running mean Temperature



Background

- Derivation of thermal limits have a long and complex history dating back to 1950s.
- Where in place, thermal limits are primarily based on laboratory derived maxima (thresholds) for important species (fish) or described as an allowable change (ΔT).
- Most commonly considered with respect to 316a CWA requirements on site specific basis.
- Effects of thermal excursion include lethality, reduced growth, disease, compromised reproductive success, migratory interruption, competition, reduction in available food resources, poor development of eggs and larvae.
- Most are not based on natural or observed thermal regimes of streams / rivers.

Status of Temperature Criteria in NE

- **CT** - No change from natural that impairs designated use with max 29.4°C limit; $\Delta T = 2.2^{\circ}\text{C}$
 - But talk to CT folks regarding 2009 proposal
- **MA** - separate criteria for cold- and warmwater fisheries
 - CWF = 20°C mean daily max over 7-day period with ΔT [0.8°C (class A); 1.7°C (class B)]
 - WWF = 28°C mean daily max over 7-day period with ΔT [0.8°C (class A); 1.7°C (class B)]
- **ME** - max limit 29.5°C; $\Delta T = 2.8^{\circ}\text{C}$
- **NH** - narrative (Env-Wq 1703.13; RSA 485-A:8,)
 - Class A waters - no change unless naturally occurring
 - Class B waters - Any stream temperature increase associated with the discharge of treated sewage, waste or cooling water, water diversions, or releases shall not be such as to appreciably interfere with the uses assigned to this class.
- **RI** - No activity to raise temperature above recommended limit on most sensitive receiving water or cause growth of undesirable or nuisance species. Max limit 28.3°C or 20°C in designated coldwaters; $\Delta T = 2.2^{\circ}\text{C}$.
- **VT** - The change or rate of change in temperature shall be controlled to ensure full support of aquatic biota, wildlife, and aquatic habitat uses with allowable limits on increase from upstream to downstream. ΔT for cold = 0.6°C; variable ΔT for warmwater depending on ambient conditions.

Thresholds based on laboratory testing

Serve as a biologically meaningful endpoints beyond which known impacts occur (toxics, pH, DO)

Relative to temperature:

Acute – Maxima based on short term survival rates (minutes to hours)

Examples: Critical thermal Maxima (CTM), Incipient Lethal Temperature (ILT), Acclimated Chronic Exposure (ACE)

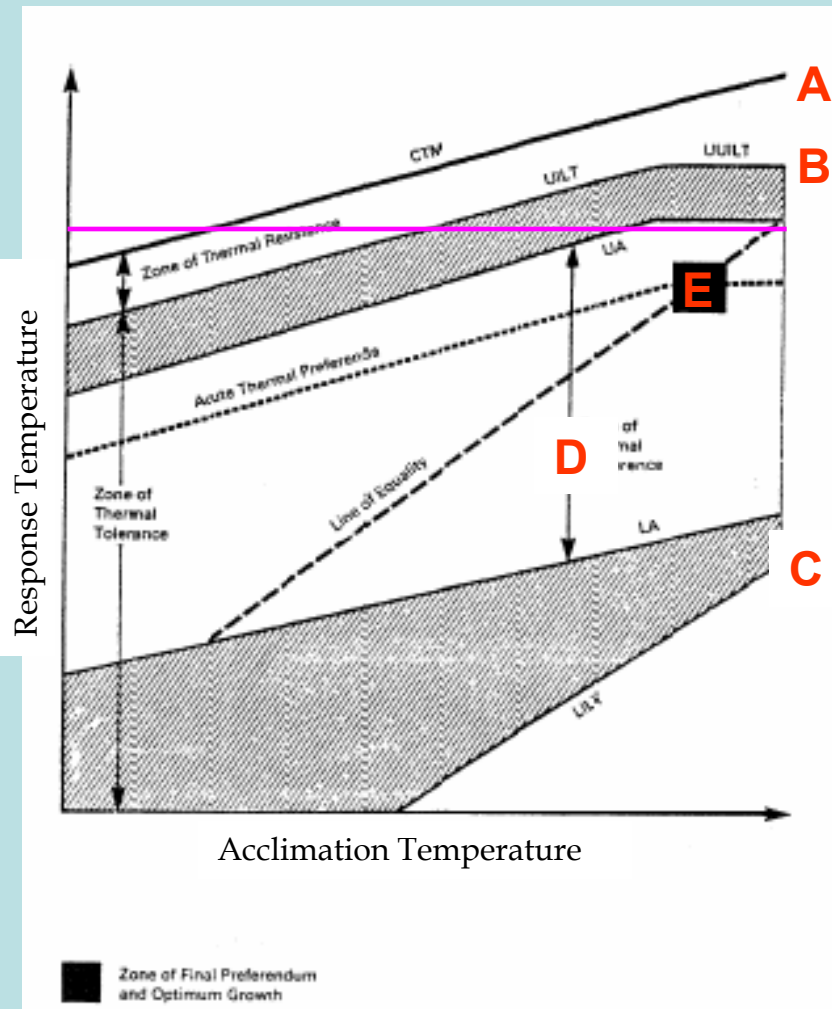
Chronic – Maxima based on long term survival and important physiological activities (growth, spawning, migration, etc.)

Examples: Optimum, Preferred, Avoidance

Focus is on chronic thresholds at this point

Criteria developed based on laboratory thresholds of thermal resistance

Theoretical relationship of fish to water temperature



(A) Upper limit critical to short-term survival (<1 hr)

(B & C) Upper and Lower Incipient Lethal Temperature (24 hours)
(Typical acute threshold)

(D) Zone of preference

(E) Optimal temperature

(—) Max 7-day Temperature

$$= \text{Optimum} + (\text{UILT} - \text{Optimum})/3$$

(Typical chronic threshold)

Adopted from Jobling (1981), Wismer and Christie 1987

Example of Laboratory Derived Thresholds

Note date of publication 1977 – I was 7 yrs. old

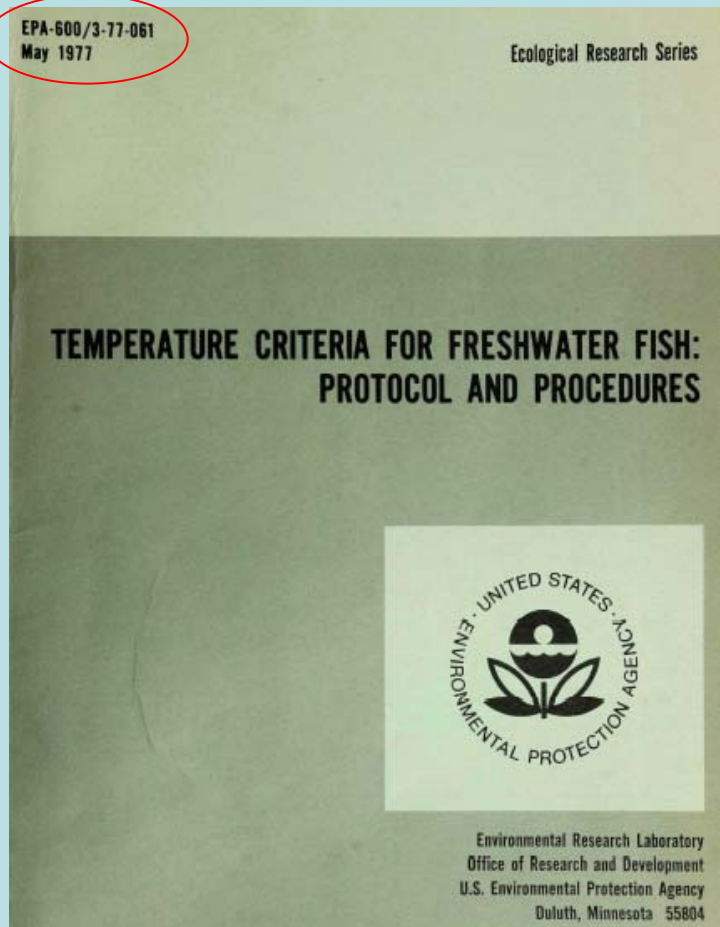


TABLE 1. TEMPERATURE CRITERIA FOR GROWTH AND SURVIVAL OF SHORT EXPOSURES (24 HR) OF JUVENILE AND ADULT FISH DURING THE SUMMER (° C (° F))

Species	Maximum weekly average temperature for growth ^a	Maximum temperature for survival of short exposure ^b
Alewife	--	--
Atlantic salmon	20 (68)	23 (73)
Bigmouth buffalo	--	--
Black crappie	27 (81)	--
Bluegill	32 (90)	35 (95)
Brook trout	19 (66)	24 (75)
Brown bullhead	--	--
Brown trout	17 (63)	24 (75)
Carp	--	--
Channel catfish	32 (90)	35 (95)
Coho salmon	18 (64)	24 (75)
Emerald shiner	30 (86)	--
Fathead minnow	--	--
Freshwater drum	--	--
Lake herring (cisco)	17 (63) ^c	25 (77)
Lake whitefish	--	--
Lake trout	--	--
Largemouth bass	32 (90)	34 (93)
Northern pike	28 (82)	30 (86)
Pumpkinseed	--	--
Rainbow smelt	--	--
Rainbow trout	19 (66)	24 (75)

Brook Trout: Acute = 24°C
Chronic = 19°C

Biologically meaningful but how do thresholds compare with ambient conditions?

Questions of interest with respect to NH in-stream temperature dataset

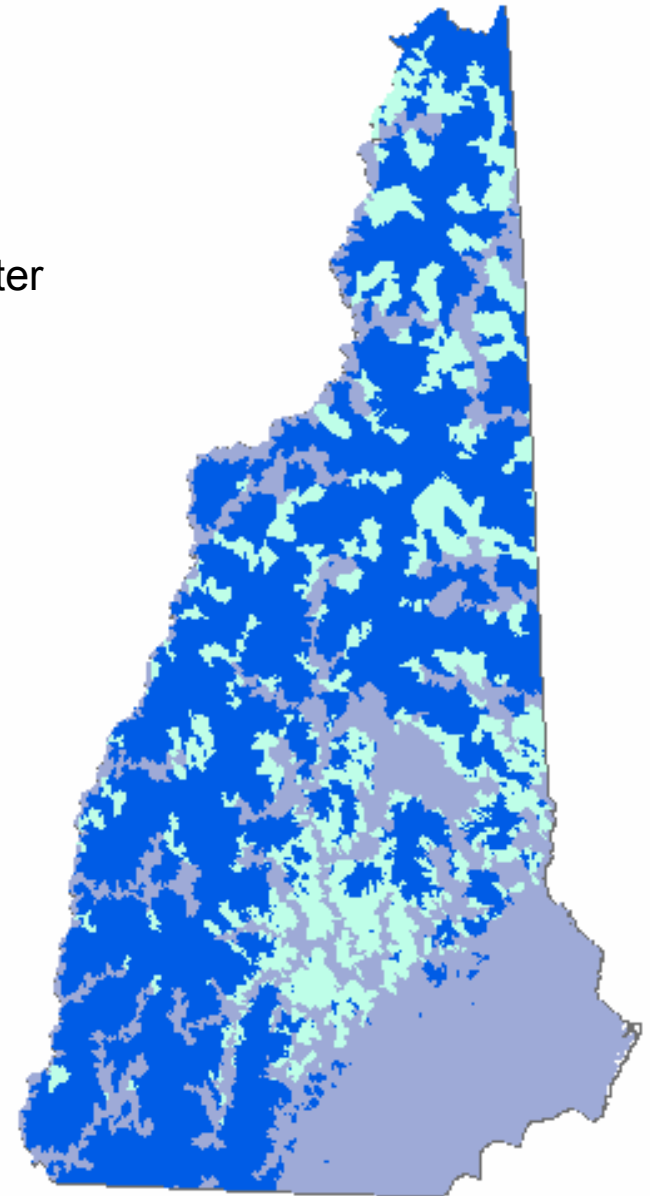
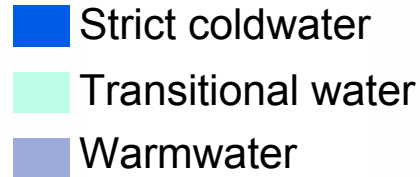
- What are the thermal regimes of NH stream types and are they unique?
- Do thermal regimes in NH stream types fit within known indicator species temperature thresholds?
- How do the temperature regimes in thermally compromised systems compare to “natural” conditions and what is the impact on biological condition (example)?
- How would criteria based on natural thermal regimes compare to threshold-based criteria?

NH Stream Types

Strict coldwater – year round support of coldwater fish species, limited species richness (2 – 4 species)

Transitional water – year round support of coldwater fish species, higher species richness (>4 species)

Warmwater – dominated by warmwater species, limited habitat for coldwater species, species richness usually >4

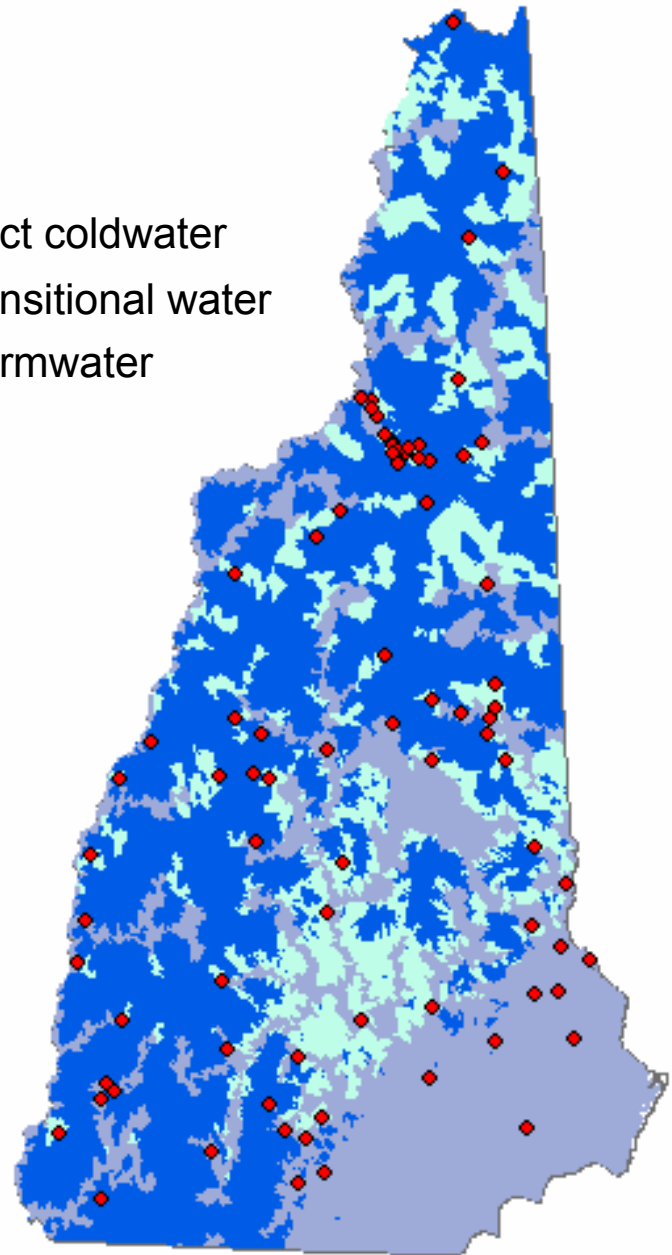


Data Collection

- 2007 - 2010
- 110 installations; 83 sites
- Coldwater = 31 sites
- Transitional water = 24 sites
- Warmwater = 28 sites
- Loggers placed in stream in June; retrieved in October
- Temperature recorded hourly



- Strict coldwater
- Transitional water
- Warmwater



Generalized Resident Fish bioperiods

- 1) March – June (spawning)
- 2) **July – September (growth) (Focus of today's presentation)**
- 3) October – December (spawning, growth)
- 4) January – March (egg/fry development, overwinter)

92 day period of record / sampling event x 24 hrs / day x 110 sampling events = ~250,000 data points

7-day running mean computed daily (primary temperature metric)

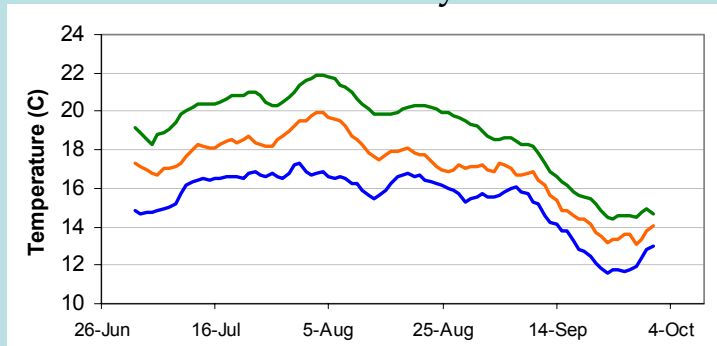
July 1 - September 30 Thermograph

— Coldwater

— Transitional water

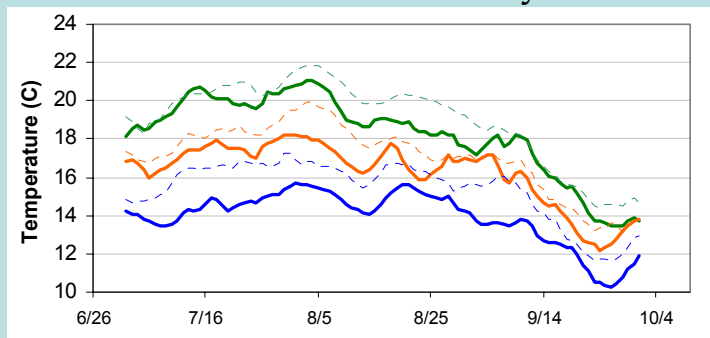
— Warmwater

All Sites - 7-day mean



- Clear separation by stream type
- $\sim 2^{\circ}\text{C}$ difference throughout summer

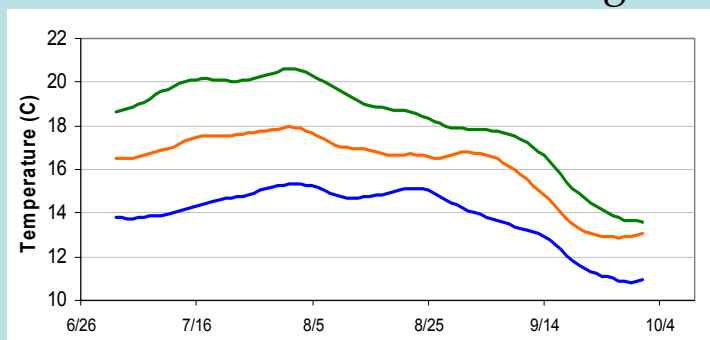
Reference Sites - 7-day mean



- Downward shift when only reference considered
- $\sim 1^{\circ}\text{C}$ less than when all sites considered

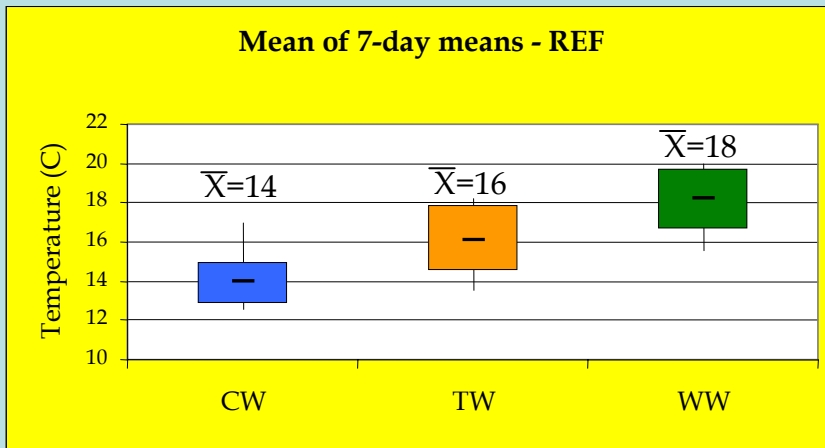
(solid line = reference only; dashed line = All sites as in plot above)

Reference Site - smoothing



- Attempt to advance dataset (1 week either side of day of measure)
- Max in late July - early August
- $5 - 6^{\circ}\text{C}$ swing during summer months

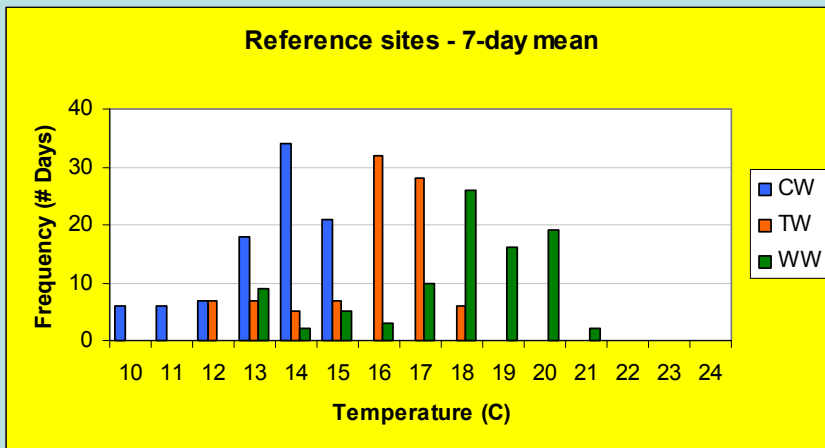
Do temperatures differ between stream types?



ANOVA of summer mean

$F=141, p<0.001$

$CW < TW < WW$



Contingency testing of frequency distribution

Chi-square = 291, $p<0.001$

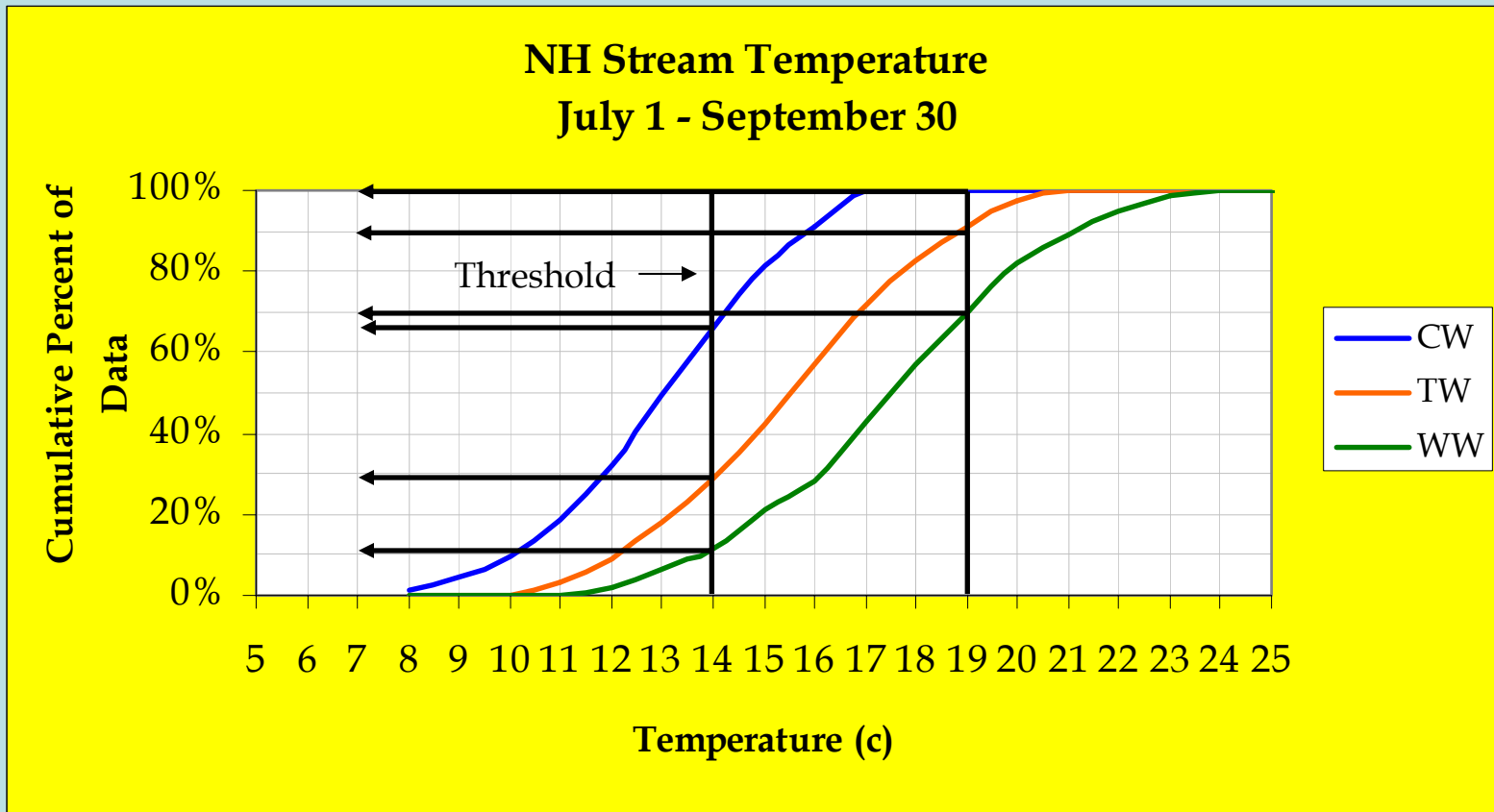
Yes,

Overall summer mean temperatures different

Frequency distribution of daily 7-day means different

Relating observed thermal regimes to biological thresholds

EXAMPLE: Brook Trout vs. 7-day mean of ref. sites



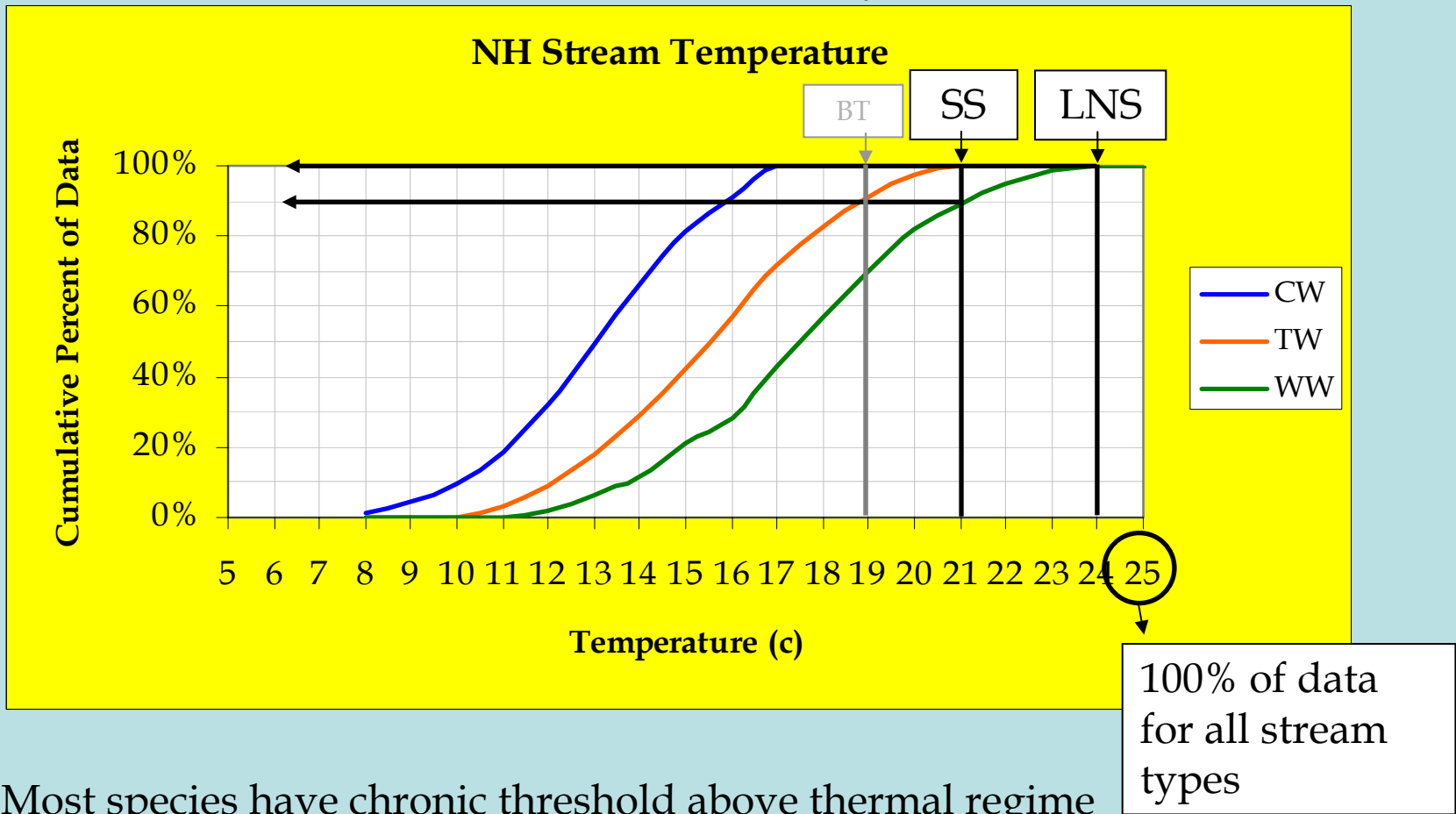
- Brook trout upper chronic threshold = 19°C
- CW streams meet threshold 100% of time
- TW streams meet threshold 90% of time
- WW streams meet threshold 70% of time

Frequently encountered species by stream type

Species	Stream type	Chronic threshold
Brook trout	CW, TW	19°C
Slimy sculpin	CW, TW	21°C (UILT-2)
Blacknose dace	CW, TW, WW	27°C (UILT-2)
Longnose sucker	TW	24°C? (UILT-2)
Longnose dace	TW, WW	unkwn
Common shiner	WW	28°C (UILT-2)
White sucker	WW	27°C
Fallfish	WW	28°C? (upper avoidance)

Relating observed thermal regimes to biological thresholds

Note: Reference sites only



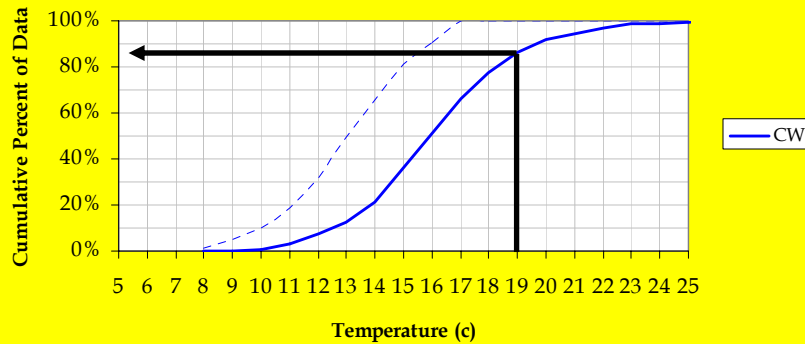
- Most species have chronic threshold above thermal regime from reference sites for all stream types
- **SS** – 100% CW & TW, 90% WW; **LNS** – 100% all stream types
- Criteria established based on biological thresholds for appropriate indicator species would fit within observed thermal regimes

Relating observed thermal regimes to biological thresholds

Non-reference sites only

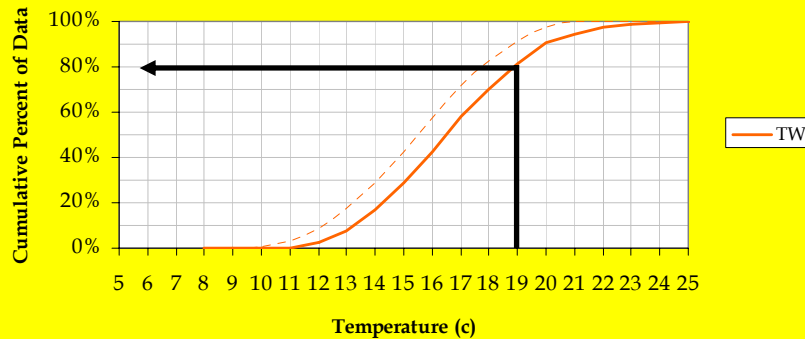
(dashed lines = reference; solid lines = non-reference)

NH Stream Temperature



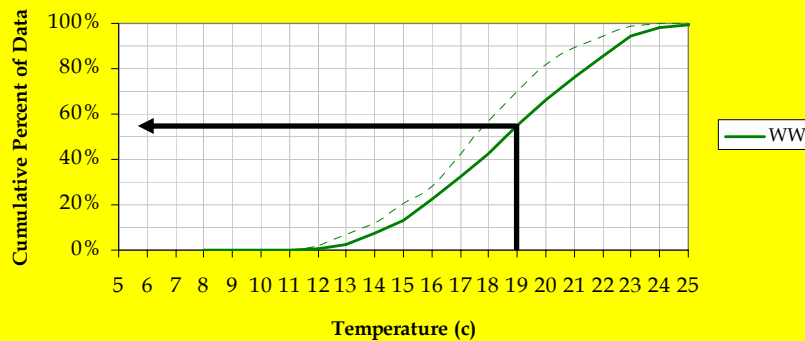
Coldwater

- ~2 - 3°C shift
- ~85% of data < brook trout threshold



Transitional water

- ~1°C shift
- Still 80% of data < brook trout threshold



Warmwater

- ~1°C shift
- Only ~55% of data < brook trout threshold
- 100% data < thresholds for WW species

Thermal regime in a compromised system

Are temperatures higher? Is there an effect on biological condition?

Otter Brook: Lancaster, NH

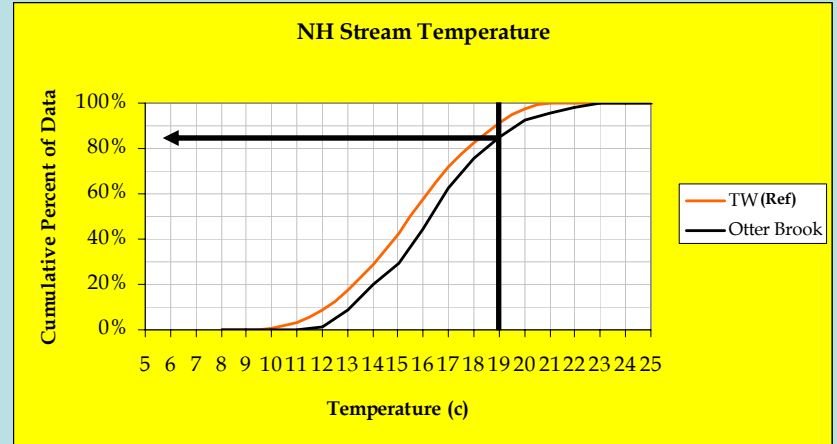
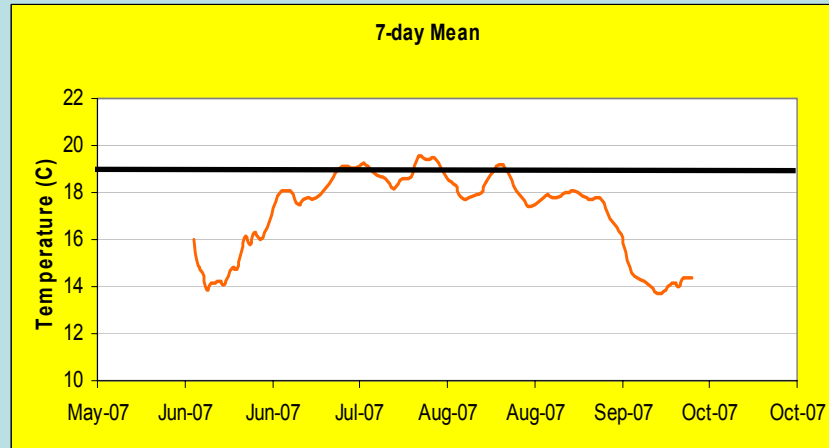
Transitional water stream

Fish sample: 2005

Temperature data: 2007 - 2010



Otter Brook thermal regime and associated biological condition



- Overall mean below or close to threshold from June 1 – Sept. 30, but
- However, ~15% of data exceeds threshold; 67 days total; avg. 17 days / yr.; 29 day period in 2010

Fish Data:

Sample ID: F05C-11-01 Collection Date: 8/2/2005 Shock Set: Duration: 1338
RepNum: 1 Collection Method: CPUE (indiv/min):

Sample Comments:

Rep. Comments:

CW probability: 0.99 Length of Reach(m):

Fish Assemblage Type: TransitionalWater

Note: Apply index appropriate to this type only

Rep	Family:	Common Name:	Total: (yoy)	DELType (num)	NumStocked
1	Cyprinidae	Creek Chub (CC)	3	None	
1	Cyprinidae	Longnose Dace (LND)	34	None	
1	Cyprinidae	Blacknose Dace (BND)	120	None	
1	Cyprinidae	Common Shiner (CS)	10	None	
1	Gadidae	Burbot (BRB)	2	None	
1	Percidae	Tessellated Darter (TD)	1	None	

New Hampshire Department of Environmental Services

Stream Biomonitoring Report

Station 05C-11

Otter Brook

Project WSAP



Transitional Water Fish Metrics (and scores)

% Brook Trout:	0.00	1	% Benthic Invertivore:	20.12	3
% CC, CS, FF:	7.69	3	% Generalist Feeder:	7.69	5
% ColdWater Taxa:	20.00	1	% Top Carnivore:	1.18	1
% Tolerant Taxa:	40.00	3	Brook Trout Age Classes:		1
			% Fluvial Specialists (excluding BND):	21.89	3
TW Index:	21		Narrative Rating:	Fails Criterion	
TW Criterion:	32				

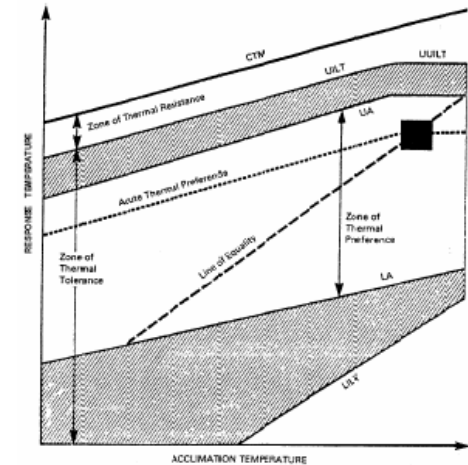
- Burbot only CW specialist; dominated species w/ higher thermal limits; fails TW IBI

Biologically-based criteria vs. Percentile

Should criteria be based on biological thresholds or the observed thermal regimes (percentiles)?

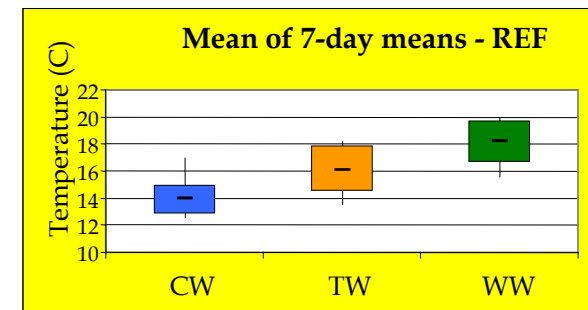
Biologically-based thresholds:

- Developed in laboratory under ideal conditions
- Limited availability for many non-game species
- May be higher than observed thermal regime
- Are meaningful endpoints that have consequences
- Sets criteria at “edge of trouble”



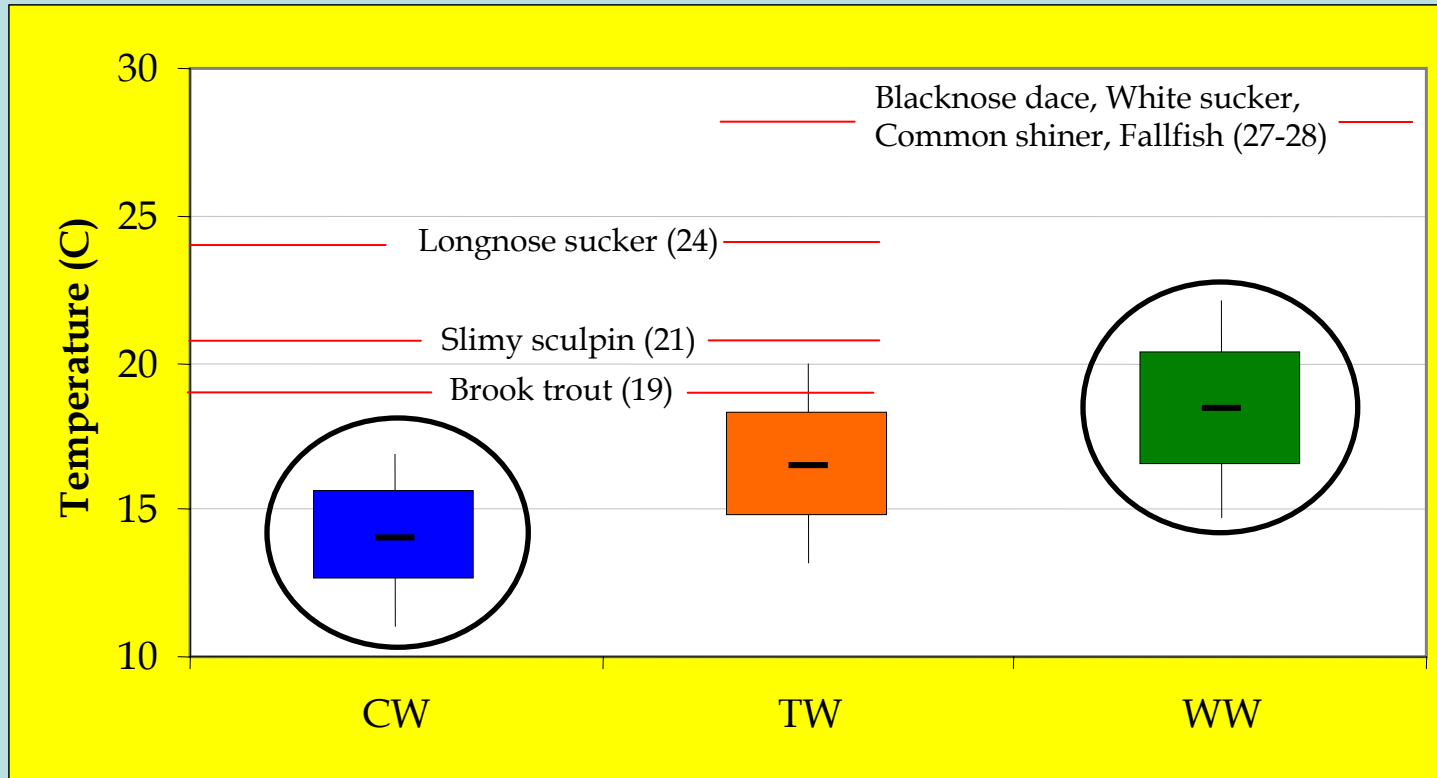
Percentile-based thresholds:

- Not tied to biological endpoints (mortality, growth, etc.)
- Could be viewed as overly restrictive
- May need adjustment in future (climate change)
- Are representative of observed conditions
- Sets criteria to conditions that fish assemblages are adapted



Percentile vs. Biologically-based criteria

July 1 – September 30 stream temperature (reference sites)



Potential thermal thresholds (°C)

Type	Percentile	Biological
CW	17	19
TW	20	19
WW	22	28

Biologically-based criteria may (TW) or may not (CW, WW) be protective of “natural” conditions.

Are percentile-based criteria justified to protect designated uses?

Summary

- 3 primary stream types in NH (CW, TW, WW).
- Each type has distinct thermal regime with $\sim 2^{\circ}\text{C}$ difference (Reference site means = 14, 16, 18°C).
- 100 % of data for CW & 90% of data for TW types below threshold for coldwater species.
- 100% of data for WW below threshold for commonly observed warmwater species.
- Data from non-reference sites represent between a 1 – 2°C shift (increase) in in-stream water temperatures.
- Thermally compromised streams can translate into reduced biological condition.
- Biologically-based thresholds may not be protective of “natural” thermal regimes; what is the justification for a percentile-based threshold that is lower?
- Future work....

Thanks!

Suggestions?